

CLAIMS

1. An apparatus for fine pattern formation comprising: a silicon substrate; a plurality of fine holes which extend through the silicon substrate from a surface of the silicon substrate to a back surface of the silicon substrate and have a silicon oxide layer on a wall surface thereof; fine nozzles which are protruded, integrally with the silicon oxide layer, on the back surface side of the silicon substrate from each opening of the fine holes; a silicon nitride layer provided on the surface and side of the silicon substrate; a support member provided on the surface side of the silicon substrate; an ink passage for supplying ink to the opening of each fine hole on the surface side of the silicon substrate; and an ink supplying device connected to the ink passage.

2. The apparatus for fine pattern formation according to claim 1, wherein the diameter of the openings in the fine nozzles is in the range of 1 to 100 μm in a variation within $\pm 1 \mu\text{m}$ and the fine nozzles are provided at a pitch in the range of 2 to 1000 μm .

3. An apparatus for fine pattern formation, comprising: a silicon substrate; a plurality of fine nozzles protruded from the back surface of the silicon substrate; a plurality of fine holes which extend at fine nozzle formed sites through the silicon substrate from the surface of the silicon substrate to the back surface of the silicon substrate and have a silicon oxide layer on the wall surface thereof; a support member provided on the surface side of the silicon substrate; an ink passage for supplying ink to the opening of each fine hole on the surface side of the silicon substrate; and an ink supplying device connected to the ink passage, said fine nozzles each comprising a nozzle base provided integrally with the silicon substrate, an inner surface layer of silicon oxide provided on the inner wall surface of nozzle bases in communication with the fine holes, and an end face layer of silicon oxide provided integrally with the inner surface layer of silicon oxide so as to cover the front end

face of the nozzle bases.

4. The apparatus for fine pattern formation according to claim 3, wherein the diameter of the openings in the fine nozzles is in the range of 1 to 100 μm in a variation within $\pm 1 \mu\text{m}$ and the fine nozzles are provided at a pitch in the range of 4 to 1000 μm .

5. The apparatus for fine pattern formation according to any one of claims 1 to 4, wherein the protrusion length of the fine nozzles is in the range of 1 to 150 μm .

6. The apparatus for fine pattern formation according to any one of claims 1 to 5, wherein the fine holes in their openings on the surface side of the silicon substrate are in the form of tapered concaves which have been widened toward the surface side of the silicon substrate.

7. The apparatus for fine pattern formation according to any one of claims 1 to 5, wherein the fine holes in their openings on the surface side of the silicon substrate are in the form of multistaged concaves which have been widened toward the surface side of the silicon substrate.

8. The apparatus for fine pattern formation according to any one of claims 1 to 7, wherein fine holes are divided into two or more groups and ink passages are provided separately from each other or one another for respective fine hole groups.

9. A process for producing a plurality of fine nozzles, formed of silicon oxide, protruded from one surface of a silicon substrate and in communication with fine holes which extend through the silicon substrate and have a silicon oxide layer on the wall surface thereof, said process comprising:

a first step of providing a silicon substrate having on its whole surface a silicon nitride layer and forming a mask pattern having a plurality of fine openings on the silicon nitride layer in its portion located on one surface of the silicon substrate;

a second step of forming through fine holes in the silicon substrate by deep etching using the mask pattern as a mask;

a third step of removing the mask pattern and oxidizing the inside of the through fine holes of the silicon substrate to form a silicon oxide layer; and

a fourth step of removing a part of the silicon nitride layer and a part of the silicon substrate from one surface of the silicon substrate by dry etching to expose the silicon oxide layer by a predetermined length, thereby forming fine nozzles.

10. The process for producing fine nozzles according to claim 9, wherein, in the fourth step, etching is started with the surface from which the mask pattern has been removed.

11. A process for producing a plurality of fine nozzles protruded from one surface of a silicon substrate, said fine nozzles comprising a nozzle base, provided integrally with the silicon substrate, and a silicon oxide end face layer covering the front end face of the nozzle base, said nozzle base being in communication with fine holes, which extend through the silicon substrate and have a silicon oxide layer on the wall surface thereof, and having a silicon oxide inner surface layer on its inner wall surface, said process comprising:

a first step of providing a silicon substrate having on its whole surface a silicon nitride layer and patterning the silicon nitride layer in its portion located on one surface of the silicon substrate to form a pattern having a plurality of small openings;

a second step of forming a mask thin film so as to cover the pattern of the silicon nitride layer and patterning the mask thin film to form a mask pattern having fine openings located within the small openings;

a third step of forming through fine holes in the silicon substrate by deep etching using the mask pattern as a mask;

a fourth step of removing the mask pattern and oxidizing sites within the through fine holes in the silicone substrate and sites exposed within the small openings to form a silicon oxide layer;

a fifth step of removing the silicon nitride layer and removing a part of the silicon substrate by dry etching using the silicon oxide layer as a mask from the surface side, on which the silicon oxide layer has been formed, to form nozzle bases having a predetermined length, thereby forming fine nozzles.

12. A process for producing a plurality of fine nozzles, formed of silicon oxide, protruded from one surface of a silicon substrate and in communication with fine holes which extend through the silicon substrate and have a silicon oxide layer on the wall surface thereof, said process comprising:

a first step of providing a silicon substrate of <100> surface crystal orientation having on its whole surface a silicon nitride layer and patterning the silicon nitride layer in its portion located on one surface side of the silicon substrate to form a pattern having a plurality of openings for taper;

a second step of etching the surface of the silicon substrate by crystallographically anisotropic etching using the silicon nitride layer as a mask to form tapered concaves;

a third step of forming a mask thin film on both surfaces of the silicon substrate and patterning the mask thin film in its portion located on the surface of the silicon substrate remote from the tapered concaves to form a mask pattern having fine openings such that the center of each fine opening substantially conforms to the center of each tapered concave through the silicon substrate;

a fourth step of forming through fine holes in the silicon substrate by deep etching using, as a mask, the mask pattern and the mask thin film;

a fifth step of removing the mask pattern and the mask thin film and oxidizing sites within the through fine holes in the silicone substrate and sites exposed within the tapered concaves to form a silicon oxide layer; and

a sixth step of removing a part of the silicon nitride layer and a part of the silicon substrate by dry etching from the surface side of the silicon substrate remote from the

tapered concaves to expose the silicon oxide layer by a predetermined length, thereby forming fine nozzles.

13. A process for producing a plurality of fine nozzles protruded from one surface of a silicon substrate, said fine nozzles comprising a nozzle base, provided integrally with the silicon substrate, and a silicon oxide end face layer covering the front end face of the nozzle base, said nozzle base being in communication with fine holes, which extend through the silicon substrate and have a silicon oxide layer on the wall surface thereof, and having a silicon oxide inner surface layer on its inner wall surface, said process comprising:

a first step of providing a silicon substrate of <100> surface crystal orientation having on its whole surface a silicon nitride layer and patterning the silicon nitride layer in its portion located on one surface side of the silicon substrate to form a pattern having a plurality of openings for taper;

a second step of etching the surface of the silicon substrate by crystallographically anisotropic etching using the silicon nitride layer as a mask to form tapered concaves;

a third step of patterning the silicon nitride layer in its portion located on the surface side of the silicon substrate remote from the tapered concaves to form a pattern having small openings such that the center of each opening substantially conforms to the center of each tapered concave through the silicon substrate;

a fourth step of forming a mask thin film on both surfaces of the silicon substrate and patterning the mask thin film in its portion located on the surface side of the silicon substrate remote from tapered concaves to form a mask pattern having fine openings located within the small openings;

a fifth step of forming through fine holes in the silicon substrate by deep etching using, as a mask, the mask pattern and the mask thin film;

a sixth step of removing the mask pattern and the mask

thin film and oxidizing sites within the through fine holes in the silicon substrate, sites exposed within the small openings, and sites exposed within the tapered concaves to form a silicon oxide layer; and

a seventh step of removing the silicon nitride layer and removing a part of the silicon substrate by dry etching using the silicon oxide layer as a mask from the surface side of the silicon substrate remote from the tapered concaves to form nozzle bases having a predetermined length, thereby forming fine nozzles.

14. A process for producing a plurality of fine nozzles, formed of silicon oxide, protruded from one surface of a silicon substrate and in communication with fine holes which extend through the silicon substrate and have a silicon oxide layer on the wall surface thereof, said process comprising:

a first step of providing a silicon substrate having on its whole surface a silicon nitride layer, forming a mask pattern having a plurality of fine openings on the silicon nitride layer in its portion located on one surface of the silicon substrate, and forming, on the silicon nitride layer on the other surface of the silicon substrate, a mask pattern having wide openings such that the center of each wide opening substantially conforms to the center of each fine opening through the silicon substrate;

a second step of forming fine holes having predetermined depth in the silicon substrate by deep etching using the mask pattern having fine openings as a mask;

a third step of forming wide concaves in the silicon substrate by deep etching using the mask pattern having wide openings as a mask in such a manner that the openings of the fine holes are exposed within the wide concaves, thereby forming multistaged concaves;

a fourth step of removing the mask pattern and oxidizing sites within the fine holes of the silicon substrate and sites exposed within the wide concaves to form a silicon oxide layer; and

a fifth step of removing a part of the silicon nitride

layer and a part of the silicon substrate from the surface of the silicon substrate remote from the wide concaves by dry etching to expose the silicon oxide layer by a predetermined length, thereby forming fine nozzles.

15. A process for producing a plurality of fine nozzles protruded from one surface of a silicon substrate, said fine nozzles comprising a nozzle base, provided integrally with the silicon substrate, and a silicon oxide end face layer covering the front end face of the nozzle base, said nozzle base being in communication with fine holes, which extend through the silicon substrate and have a silicon oxide layer on the wall surface thereof, and having a silicon oxide inner surface layer on its inner wall surface, said process comprising:

a first step of providing a silicon substrate having on its whole surface a silicon nitride layer and patterning the silicon nitride layer in its portion located on one surface of the silicon substrate to form a pattern having a plurality of small openings;

a second step of forming a mask thin film so as to cover the pattern of the silicon nitride layer and then patterning the mask thin film to form a mask pattern having fine openings located within the small openings, and, in addition, patterning the mask thin film on the other surface to form a mask pattern having wide openings such that the center of each wide opening substantially conforms to the center of each fine opening through the silicon substrate;

a third step of forming fine holes having predetermined depth in the silicon substrate by deep etching using the mask pattern having fine openings as a mask;

a fourth step of forming wide concaves in the silicon substrate by deep etching using the mask pattern having wide openings as a mask in such a manner that the openings of the fine holes are exposed within the wide concaves, thereby forming multistaged concaves;

a fifth step of removing the mask pattern and oxidizing sites within the fine holes of the silicon substrate, sites

exposed within the wide concaves, and sites exposed within the small openings to form a silicon oxide layer; and

a sixth step of removing the silicon nitride layer and removing a part of the silicon substrate by dry etching using the silicon oxide layer as a mask from the surface of the silicon substrate remote from the wide concaves to form nozzle bases having a predetermined length, thereby forming fine nozzles.

16. An apparatus for fine pattern formation comprising: a silicon substrate; a plurality of fine holes which extend through the silicon substrate from the surface of the silicon substrate to the back surface of the silicon substrate and have a silicon oxide layer on the wall surface thereof; fine nozzles which are protruded, integrally with the silicon oxide layer, on the back surface side of the silicon substrate from each opening of the fine holes; a reinforcing layer provided at least on the front end face and outer face of the fine nozzles; a support member provided on the surface side of the silicon substrate; an ink passage for supplying ink to the opening of each fine hole on the surface side of the silicon substrate; and an ink supplying device connected to the ink passage.

17. The apparatus for fine pattern formation according to claim 16, wherein the thickness of the reinforcing layer is at least twice the thickness of the fine nozzles.

18. The apparatus for fine pattern formation according to claim 17, wherein the reinforcing layer is formed of any one of silicon oxide and phosphorus silicon glass.

19. The apparatus for fine pattern formation according to any one of claims 16 to 18, wherein the fine nozzles have an opening diameter in the range of 1 to 100 μm and are provided at a pitch in the range of 4 to 1000 μm .

20. The apparatus for fine pattern formation according to any one of claims 16 to 19, wherein the fine nozzles have a projection length in the range of 10 to 400 μm .

21. The apparatus for fine pattern formation according to any one of claims 16 to 20, wherein the fine holes in their

openings on the surface side of the silicon substrate are in the form of tapered concaves which have been widened toward the surface side of the silicon substrate.

22. The apparatus for fine pattern formation according to any one of claims 16 to 20, wherein the fine holes in their openings on the surface side of the silicon substrate are in the form of multistaged concaves which have been widened toward the surface side of the silicon substrate.

23. The apparatus for fine pattern formation according to any one of claims 16 to 22, wherein the fine holes are divided into two or more groups and ink passages are provided separately from each other or one another for respective fine hole groups.

24. The apparatus for fine pattern formation according to any one of claims 16 to 23, wherein a water-repellent layer is provided at least on the reinforcing layer, provided on the outer face of the fine nozzles, and on the back surface side of the silicon substrate.

25. The apparatus for fine pattern formation according to claim 24, wherein the water-repellent layer is formed of fluorocarbon.

26. An apparatus for fine pattern formation, comprising: a silicon substrate; a plurality of fine holes provided so as to extend through the silicon substrate from the surface of the silicon substrate to the back surface of the silicon substrate; a main electrode provided on the surface side of the silicon substrate; a counter electrode provided on the back surface side of the silicon substrate while leaving a predetermined space between the main electrode and the counter electrode; a support member provided on the surface side of the silicon substrate; an ink passage for supplying ink to openings in the fine holes on the surface side of the silicon substrate; and an ink supplying device connected to the ink passage.

27. The apparatus for fine pattern formation according to claim 26, wherein nozzles are protruded on the back surface side of the silicon substrate from the openings of the fine

holes.

28. The apparatus for fine pattern formation according to claim 27, wherein the wall surface of the fine holes has a silicon oxide layer and the nozzles are formed of silicon oxide.

29. The apparatus for fine pattern formation according to any one of claims 26 to 28, wherein the counter electrode is in a drum or flat plate form.

30. The apparatus for fine pattern formation according to any one of claims 26 to 29, wherein the fine holes have an opening diameter in the range of 1 to 100 μm and are provided at a pitch in the range of 2 to 1000 μm .

31. The apparatus for fine pattern formation according to any one of claims 27 to 30, wherein the nozzles have a protrusion length in the range of 10 to 400 μm .

32. The apparatus for fine pattern formation according to any one of claims 26 to 31, wherein the fine holes in their openings on the surface side of the silicon substrate are in the form of tapered concaves which have been widened toward the surface side of the silicon substrate.

33. The apparatus for fine pattern formation according to any one of claims 26 to 31, wherein the fine holes in their openings on the surface side of the silicon substrate are in the form of multistaged concaves which have been widened toward the surface side of the silicon substrate.

34. The apparatus for fine pattern formation according to any one of claims 26 to 33, wherein fine holes are divided into two or more groups and ink passages are provided separately from each other or one another for respective fine hole groups.

35. The apparatus for fine pattern formation according to claim 34, wherein main electrodes are separately provided for respective fine hole groups.

36. A method for fine pattern formation, comprising the step of: while relatively scanning the apparatus for fine pattern formation according to any one of claims 26 to 35 and a pattern object in a predetermined direction,

continuously or intermittently ejecting ink supplied at low pressure from the ink passage onto the pattern object through the fine holes in such a state that a voltage is applied to the main electrode in the apparatus for fine pattern formation, whereby a stripe pattern or a dot pattern is formed.

37. The method for fine pattern formation according to claim 36, wherein stripes constituting the pattern are formed by supplying ink through a plurality of fine holes arranged on an identical line along the scanning direction.

38. A method for fine pattern formation, comprising the steps of: disposing the apparatus for fine pattern formation according to any one of claims 26 to 35 at a predetermined position of a pattern object; and ejecting a given amount of ink supplied at low pressure from the ink passage onto the pattern object through the fine holes in such a state that a voltage is applied to the main electrode of the apparatus for fine pattern formation, whereby a pattern is formed.

39. A method for fine pattern formation according to any one of claims 36 to 38, wherein the voltage applied to the main electrode is regulated to control ink ejection width and the amount of ink ejected.